ISS Utilization Status and Plans

NASA Advisory Council
Commercial Space Committee

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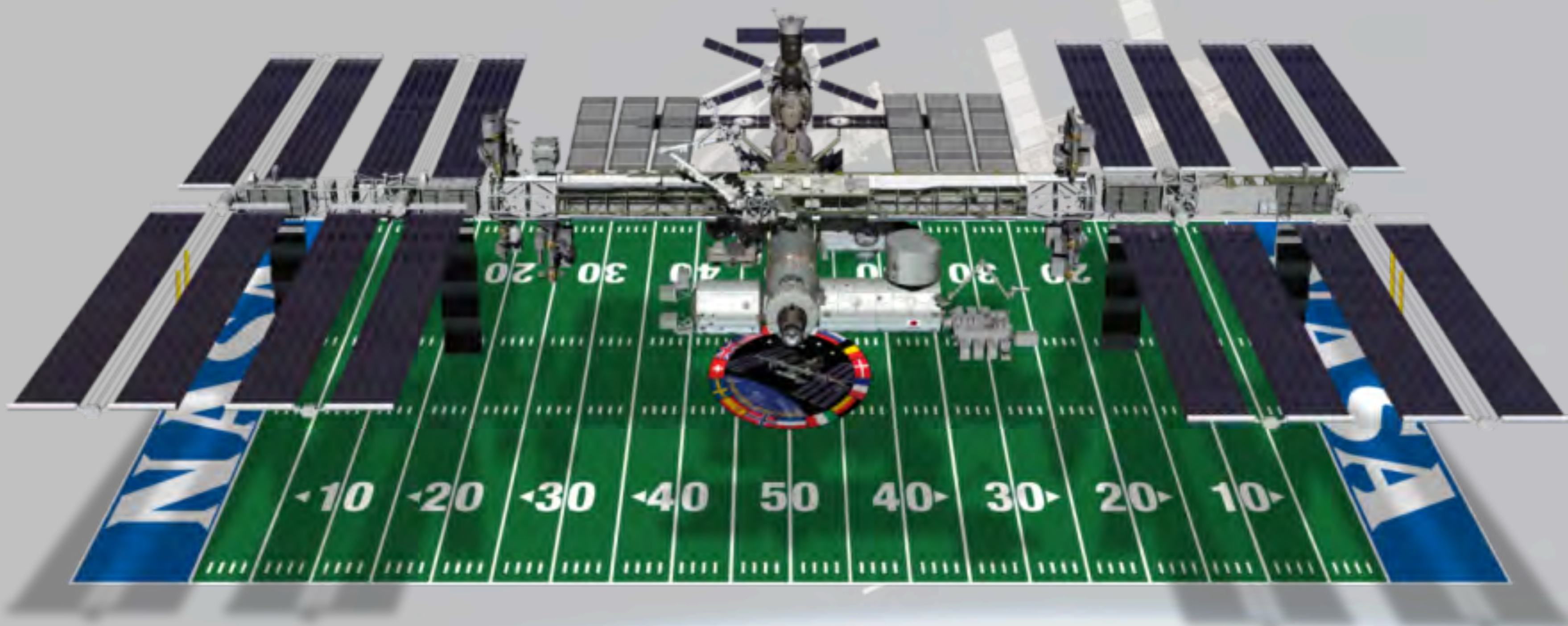
NASA

1 March 2013

International Space Station



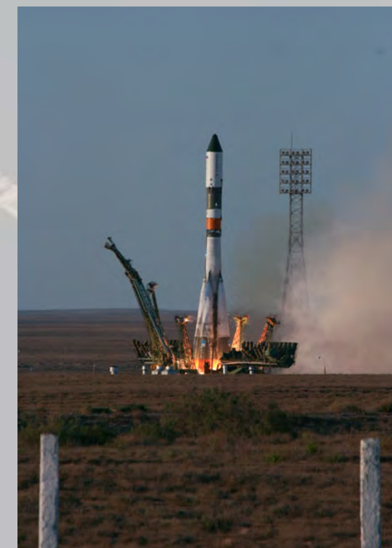
- *Spacecraft Mass : 409,194 kg (902,119 lb)*
- *Spacecraft Pressurized Volume: 917 m3 (32,333 ft3)*
- *Velocity: 28,164 km/h (17,500 mph) = 7823.2 m/s (a bullet from a high powered rifle travels at ~1500 m/s)*
- *The solar array surface area: 3567 m2 (38,400 ft2) = 0.88 acre*
- *Science Capability: Laboratories from four international space agencies - US, Europe, Japan, and Russia*
- *On-orbit construction: Began in 1988, 37 space shuttle flights, 4 Russian assembly launches, and over 150 spacewalks*

U.S. Led International Operations

United States | Russia | Canada | Europe | Japan

Transportation to Space Station

- More than 100 launches by five agencies
- By Canada, Europe, Japan and Russia
- Russian transportation
  - Four Soyuz trips annually w/ 3 crew members
  - 12 Crew members for expeditions through 2014
  - 15 resupply vehicles over next three years
  - 33 Soyuz and 50 Progress flights completed
  - 2 commercial cargo flights, SpaceX demo and SpaceX 1

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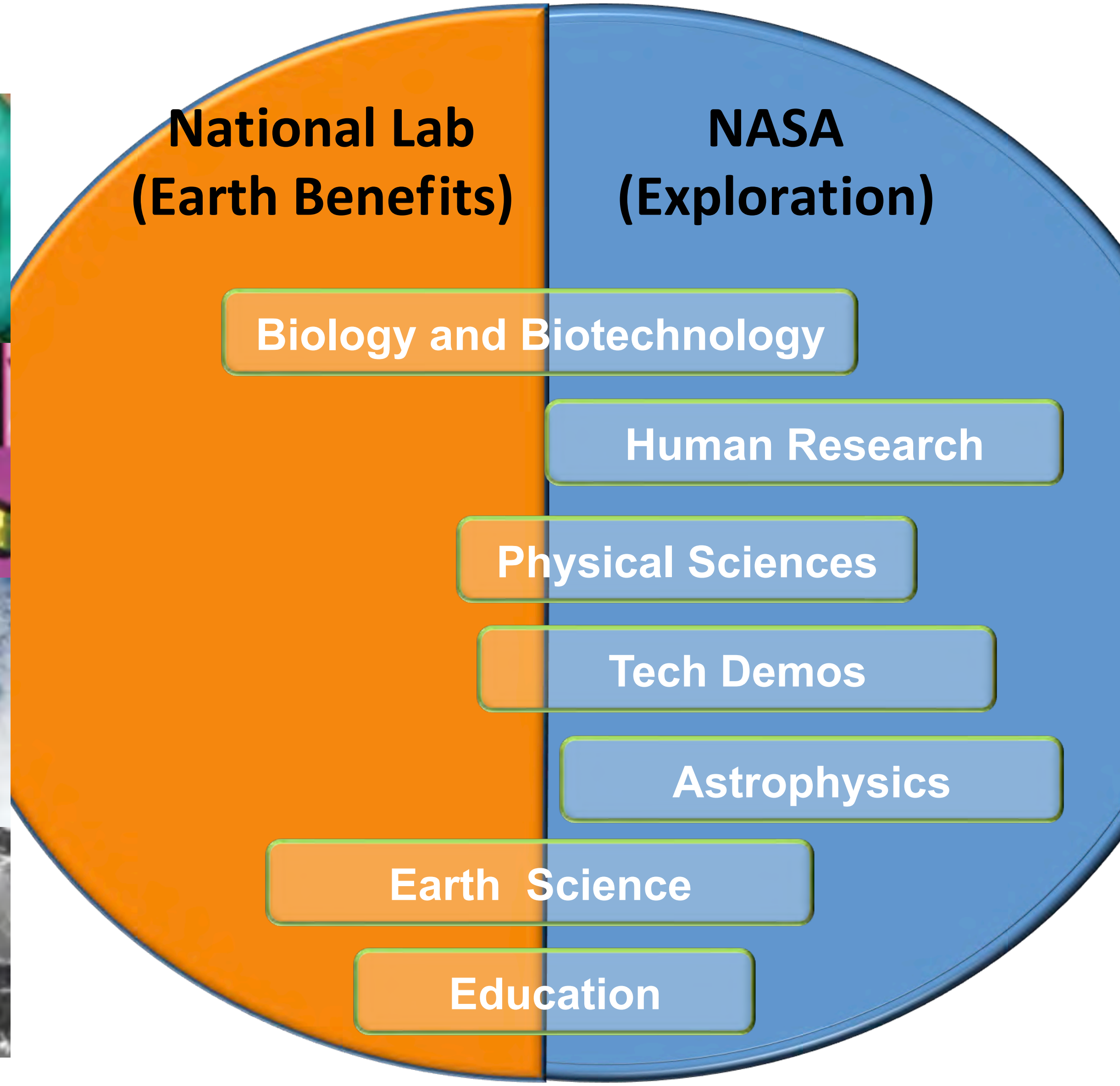
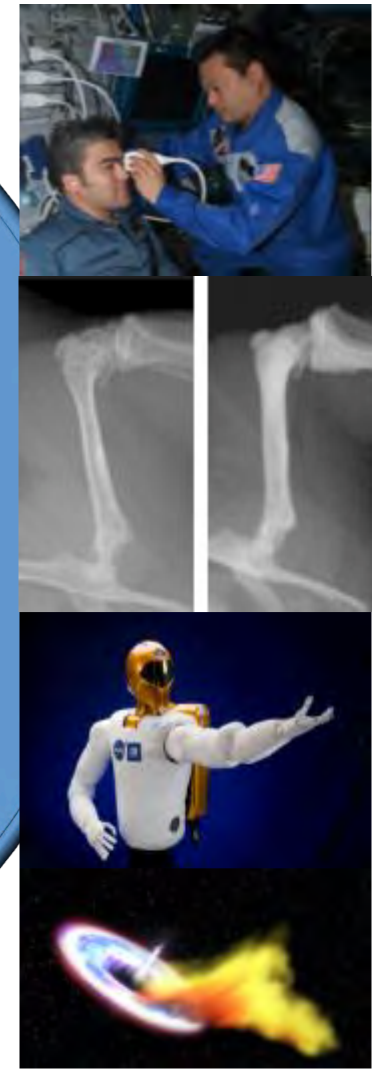
OFF THE EARTH... FOR THE EARTH

Presentation Overview

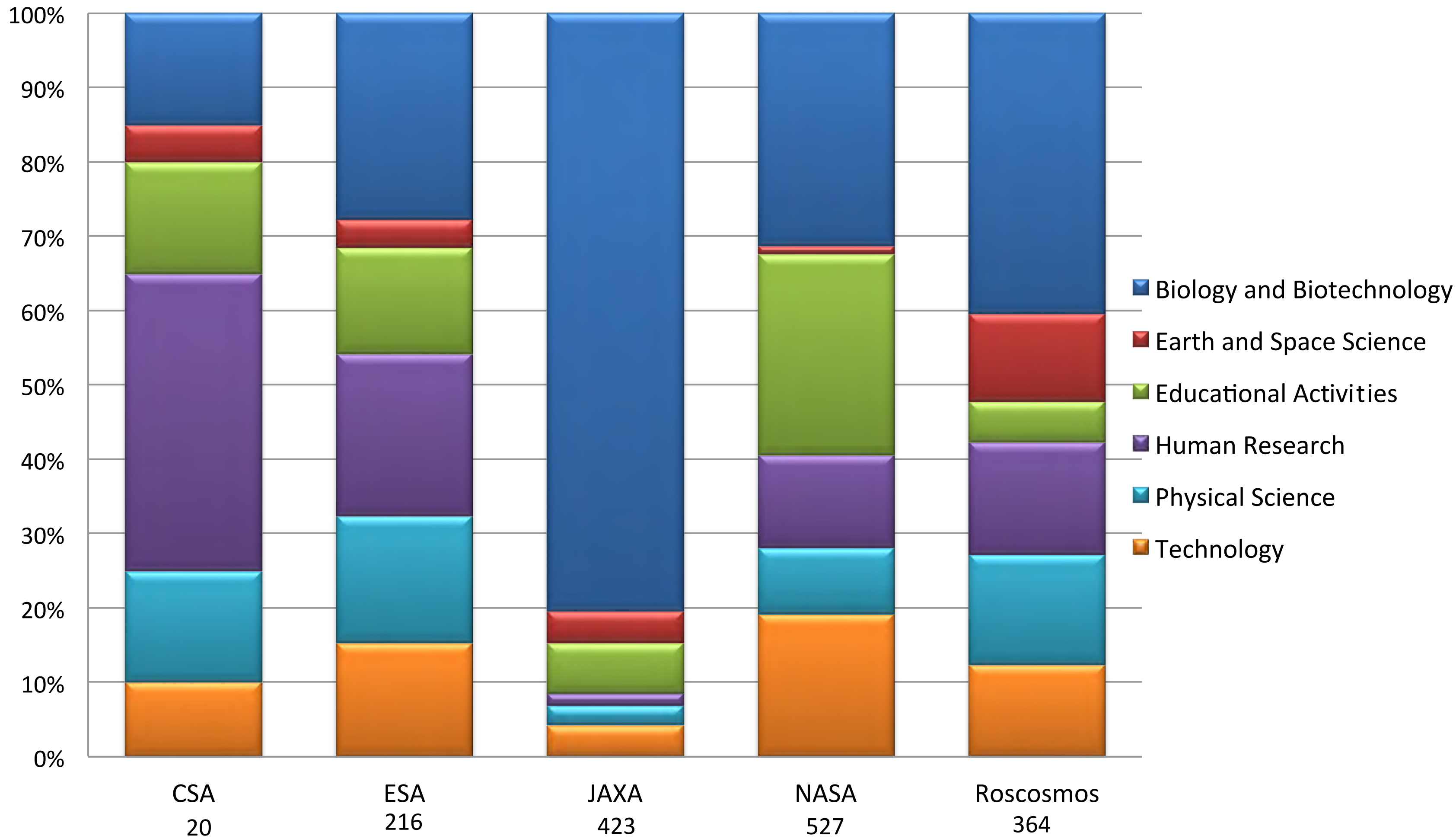
- What are we doing on ISS today?
  - Disciplines
  - Record throughput
  - Growth of ISS National Lab/CASIS-sponsored research
- What is “full utilization” of ISS and what role does commercial space play?
- Enabling greater scientific return
- Communicating about ISS and its accomplishments

What are we doing on ISS today?



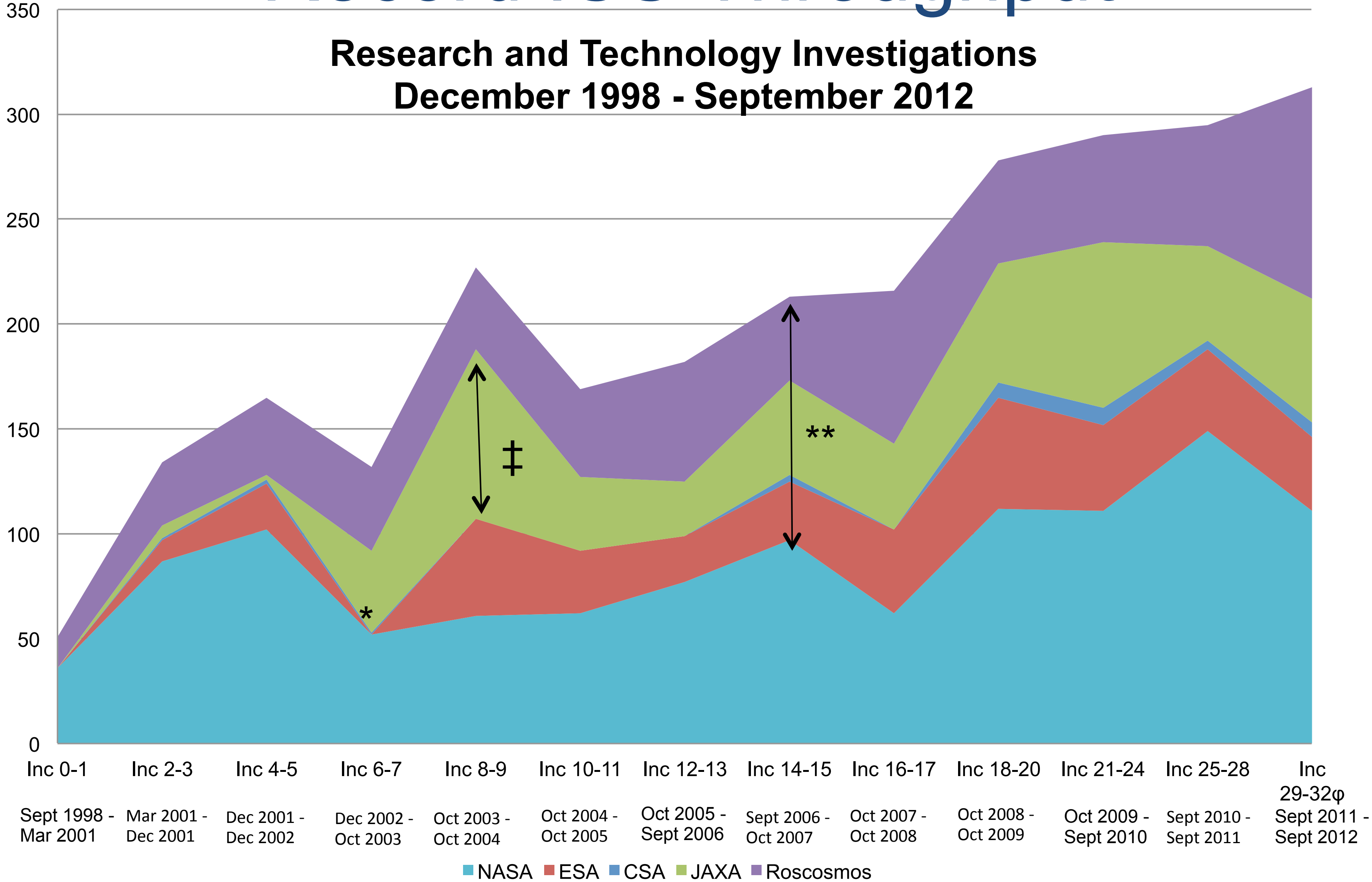


Research Disciplines of ISS Investigations* By Partner Agency: Expeditions 0-32; 1550 Total Investigations December 1998 - September 2012



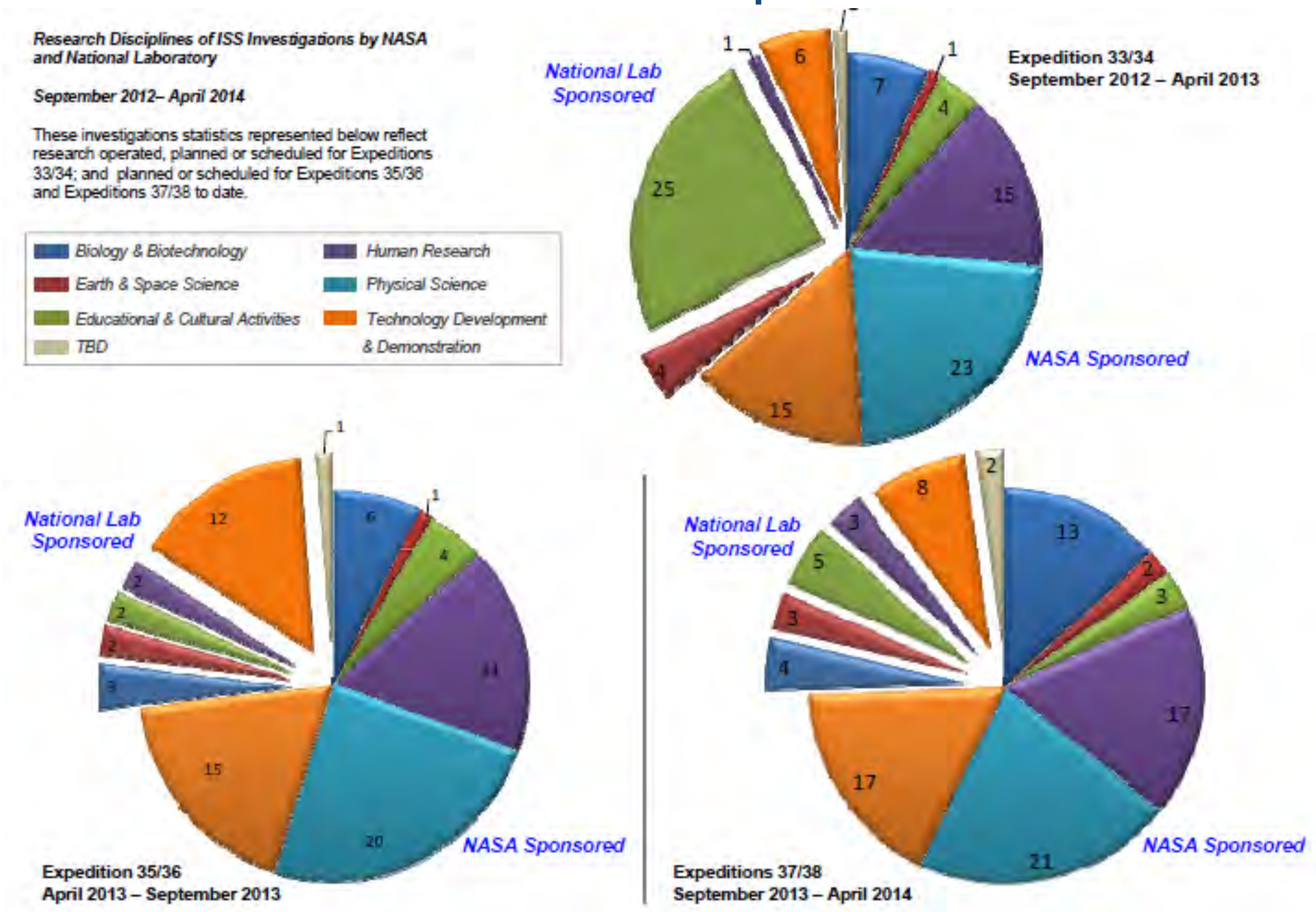
*Numbers are under review

Record ISS Throughput



* Post- Columbia ‡ Japanese investigation surge in protein crystal growth ** Shuttle Return to Flight φ Estimated Numbers

ISS National Laboratory as a portion of the US research portfolio

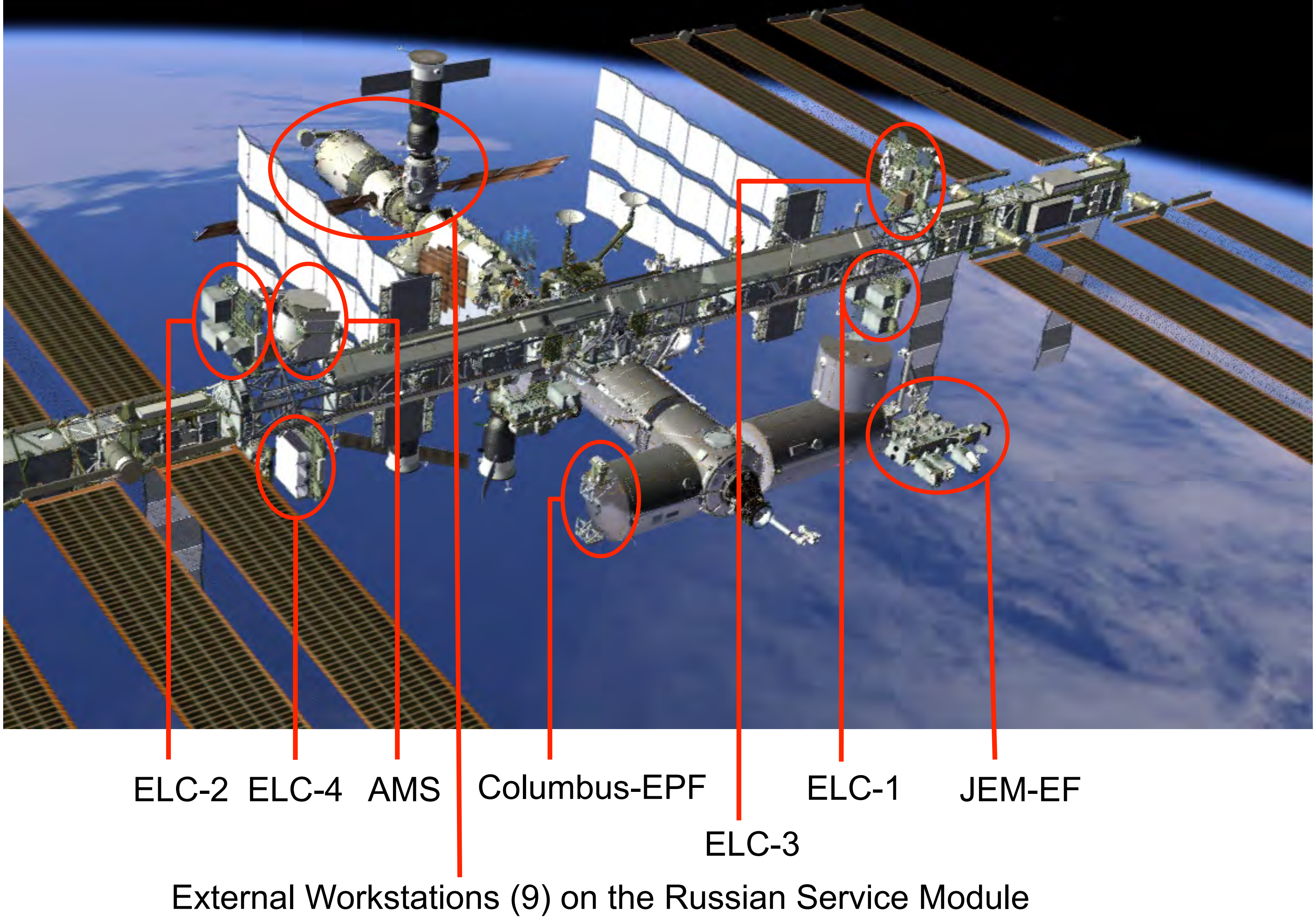


Growth of ISS National Lab

- From 2005-2012 “National Lab Pathfinders”
  - By 2011, Approximately 25% of ISS investigations were National Lab Pathfinders
- 2011-2013 Transition to CASIS management
  - First research solicitations open now
  - First CASIS-selected experiments will fly in Expeditions 37/38 (about 1 year from now)
  - Some pathfinders will end, some will transition to CASIS management

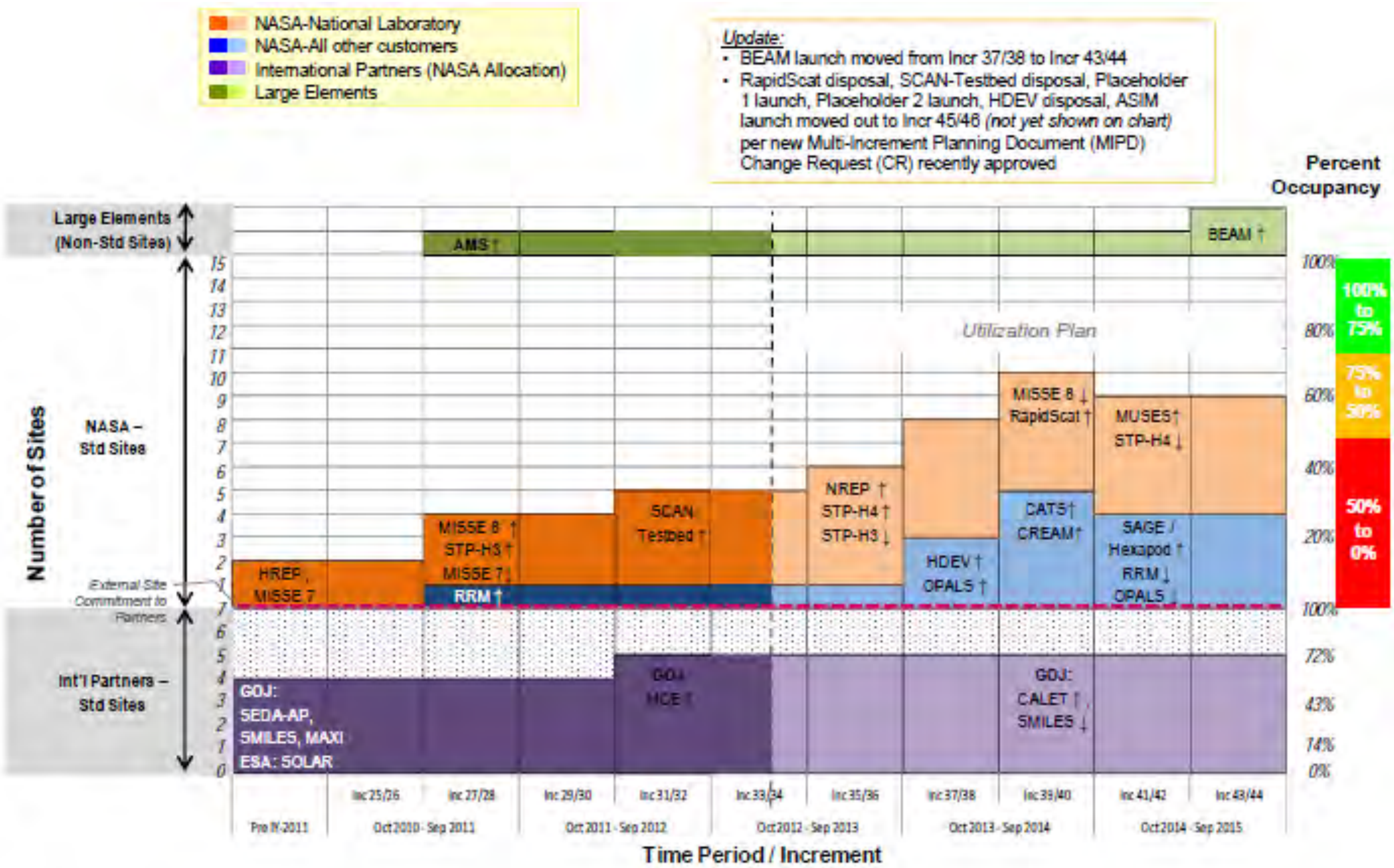
External Facilities

Overview of External Payload Attachment Sites



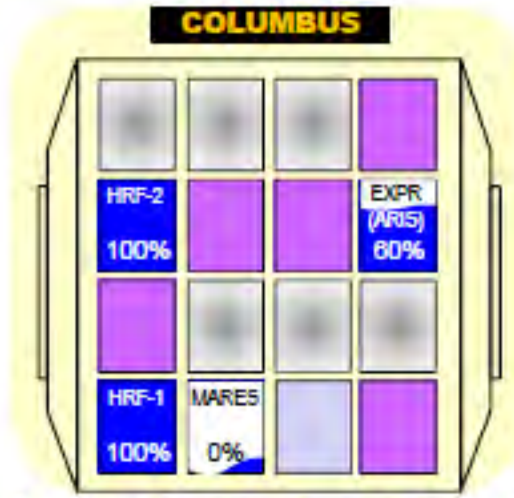
External Instrument Sites

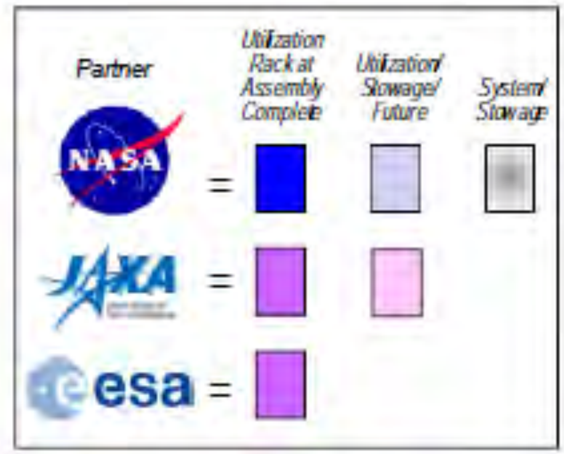
All good Earth- and nadir-viewing sites full by 2016

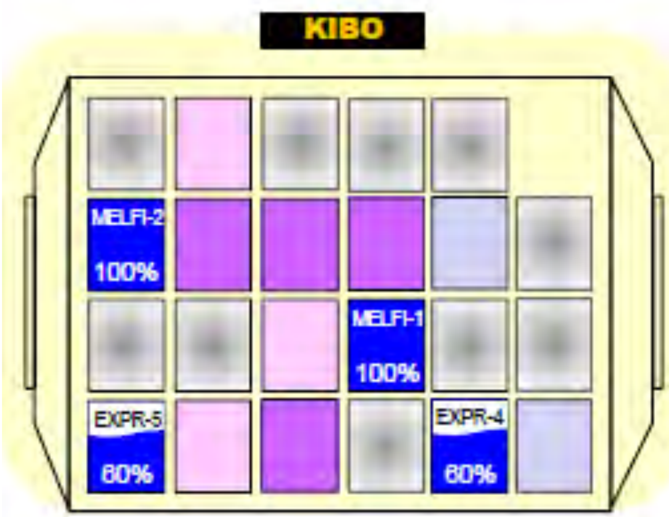


Internal Facilities

Internal Rack Capacity







U.S. Facility Occupancy – Current To Date and Planned by End of FY 2013

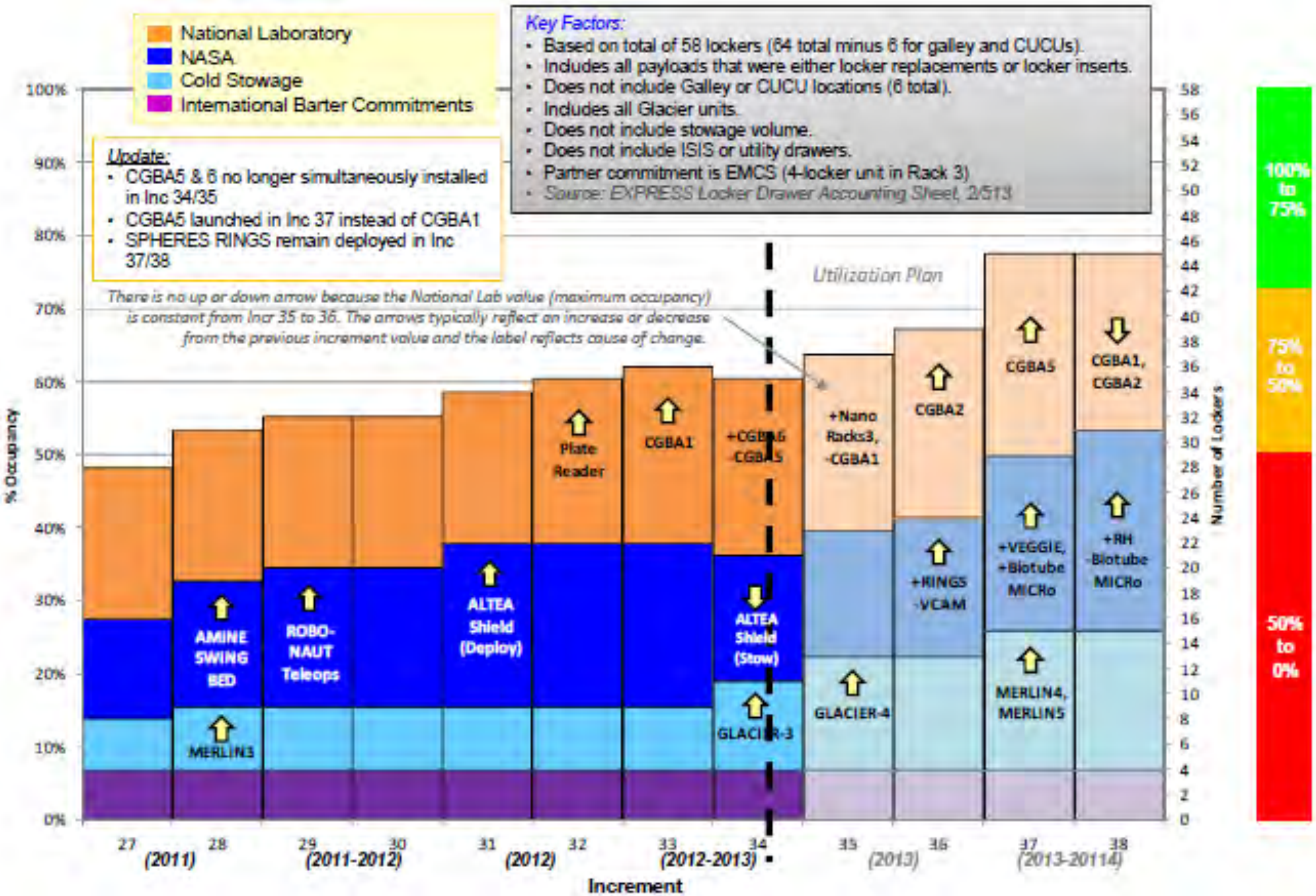
Facility	Notes	To-Date Percentage	Planned End of FY13 Percentage	Number of Racks (Weighting Factor)
EXPRESS	45 of 58 lockers (*@ end of FY13*)	60%	78%	7.25 Racks (excluding Galley & CLICU)
HRF	Standby equipment	100%	100%	2
MARES	First use in FY13 (*Assumes first use of ESA SARCOLAB experiment runs from June to Oct*)	0%	33%	1
MSG	*Planned for FY13:* SODI, BASS, INSPACE-3, CSLM-3, CCF, SODI	100%	97%	1
CIR	*Planned for FY13:* FLEX-2, ICE-GA	100%	100%	1
FIR	*Planned for FY13:* ACE-M, CVB-2, ACE-M2 *(Difference in YTD from last month due to the decision to stop ACE-LA runs until new samples arrive on SpX-2)*	0%	58%	1
MSRR/ MSL	Assumed full at 2 cartridges/month (*No experiments til Jan, then 4 months at 1/2 capacity and 4 months at full capacity*)	0.5%	50%	0.66
MSRR Open Bay	Currently used for payload stowage but scarred for payload	0%	0%	0.34
WORF	ISSAC, ISERV (*planned for installation*), EarthKAM	90%	96%	1
MELFI	3 MELFIs full or standby	100%	100%	3
	Total	12.61	14.80	18.25
	Weighted Percentage	69.1%	81.0%	–

Chart prepared by Roger H. Weiss (Barrios/MRI), NASA/JSC ISS OF [illegible]

__Update__

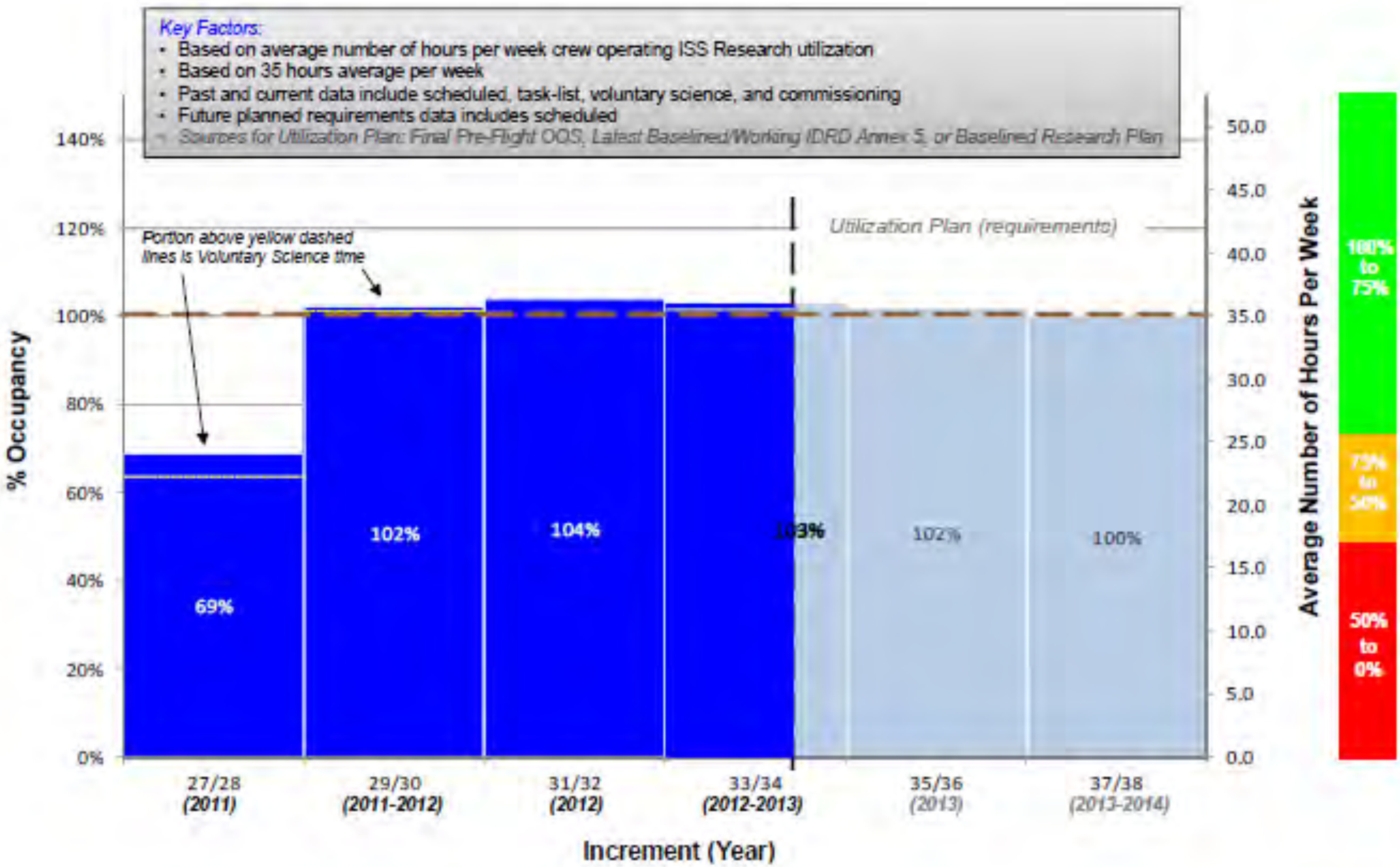
- *EXPRESS dropped to 60.3% from 64% based on a locker coming down (CGBA-5) and stowage of ALTEA*
- *EXPRESS year-end calculation corrected to 77.6% from 74%; 45 out of 58 vs. 43 out of 58.*
- *Overall year-end prediction changes to 81.0% from 80.5%*
- *MSRR picks back up with MICAST processing and jumps to 50% occupancy last month with the sample processing*
- *WORF drops slightly to 90% due to changeout from EarthKAM to ISERV*
- *Overall YTD down to 71.8% from 72%*

Facilities in Express Racks



USOS Crew Time

Now at strategic goal (USOS 35 hrs/wk), but our users need more



How do we know we are at full utilization?

- Real estate bottom line:
  - Racks 71% occupied
  - EXRESS 60% occupied, expect 80% by the end of 2014
  - External Sites 35% occupied, expect 75% by end of 2014
  - Best external sites (best viewing with good Nadir or Zentith views) are mostly claimed through 2020
- Crew time bottom line:
  - Scheduled time oversubscribed (>100%)
  - Crew as human subjects oversubscribed (multi-year queue carefully managed by HRP, a big issue for our partners, limits CASIS research)
  - NASA and CASIS users are soon going to compete for this limited resource unless we are able to expand availability
- Upmass/downmass bottom line:
  - Mass not limiting--No backlog on the ground today, projected mass capacity is good
  - Our on-orbit freezers are nearly full (>100%), dependent on regular SpaceX return
  - User demand for powered launch and return cannot be met (>100%) due to Biotech and Biology interest

Major factors influencing research use of ISS

Lack of research funding

Resource limitations (e.g., upmass, downmass, crewtime)

- Flight delays to resupply and return plan
- Operations scenarios that reduce crew time for research

Cost to use the platform

- Transportation costs (now provided for all)
- Costs of payload development (National Lab enabling funding)

Strategies to tip the balance: diverse transportation providers, procure upmass for more users, simplify integration, communicate successes

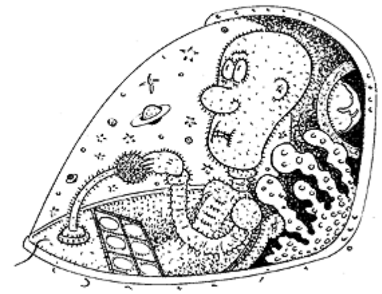
Research Demand

- NASA Funding
- Non-NASA Funding
- Research breakthroughs that drive funding (Earth benefits & applications)

Enabling greater scientific return

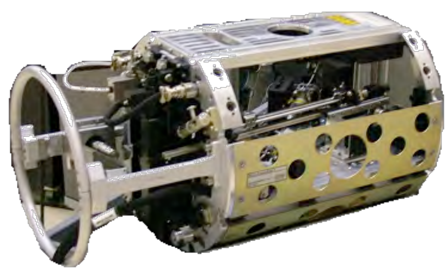
Rodent Research System

Drosophila Habitat and Centrifuge

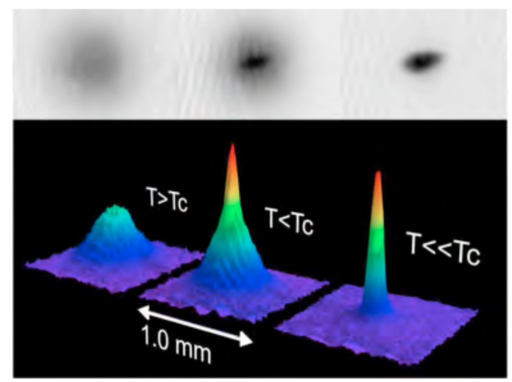


“Microbial Observatory”

Advanced Plant Habitat



ACME Gaseous Combustion

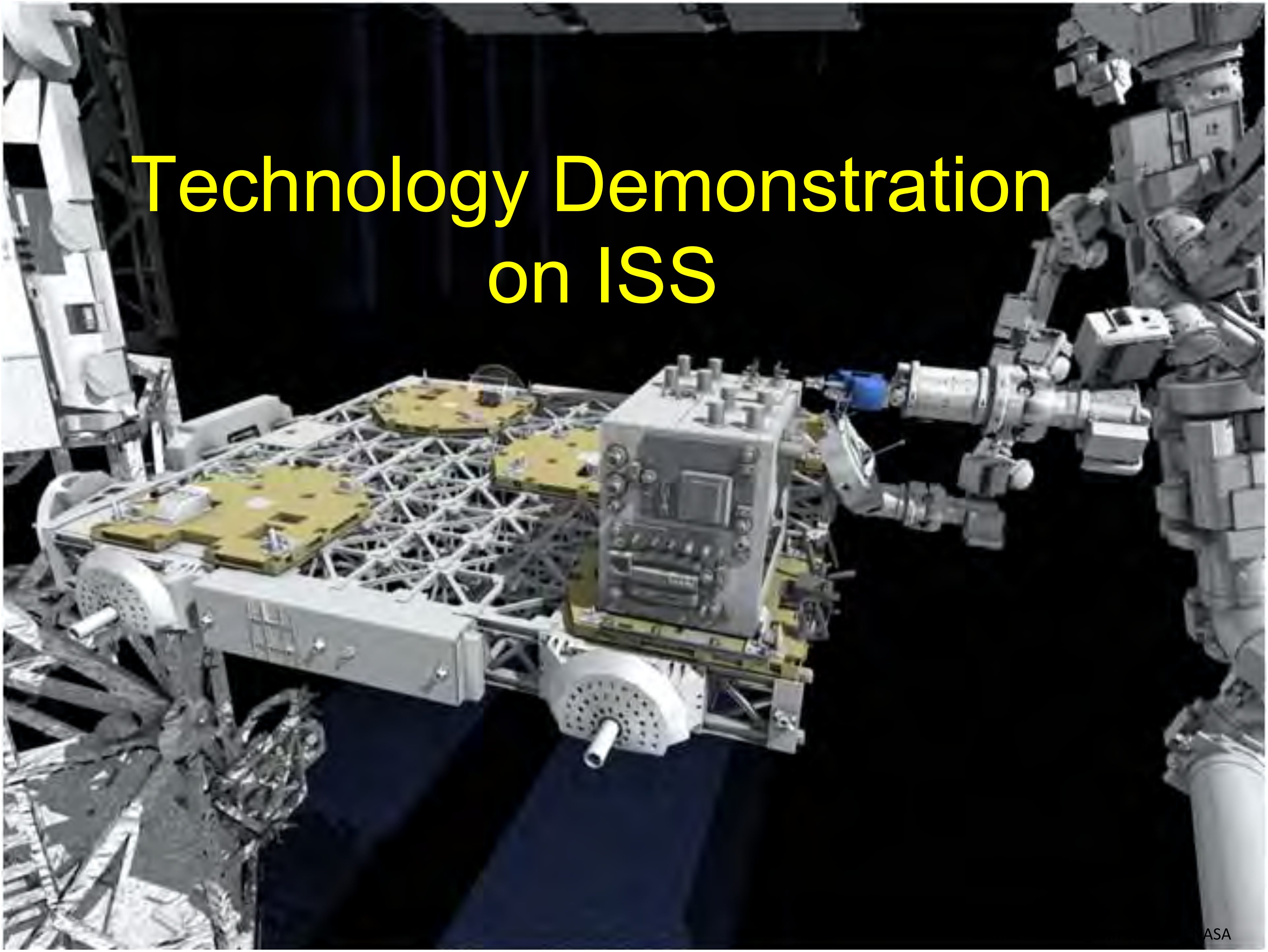


Cold Atom Laboratory

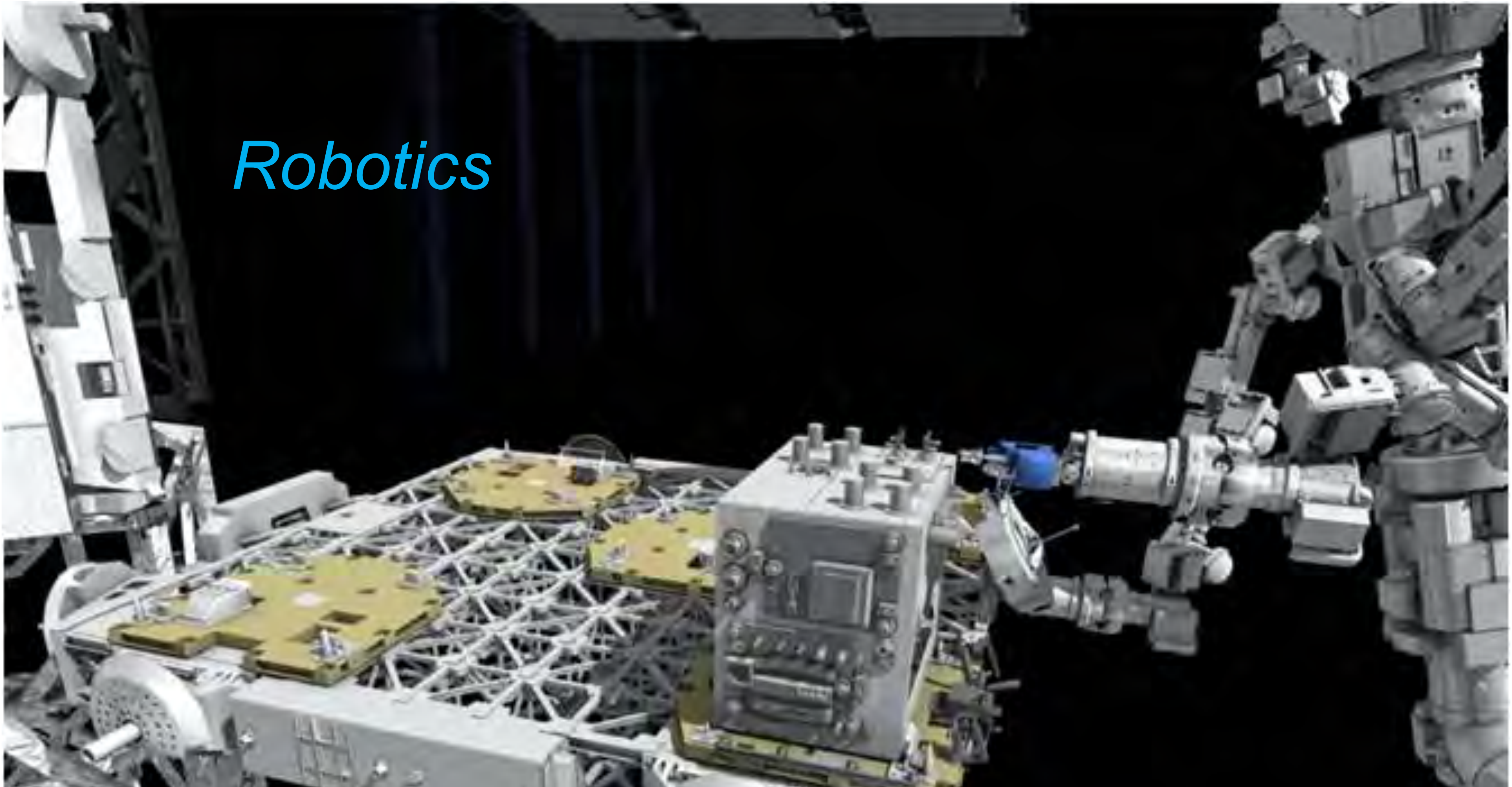
ISS Role in Commercial Space

- Customer for commercial launches
  - Cargo
  - Crew
- Enable future commercial research platforms that could follow in LEO
- Access to ISS as a research and development platform for commercial users
  - Biotech/Pharma
  - Aerospace Industry
  - Materials Industry
  - Commercial Remote Sensing

Technology Demonstration on ISS



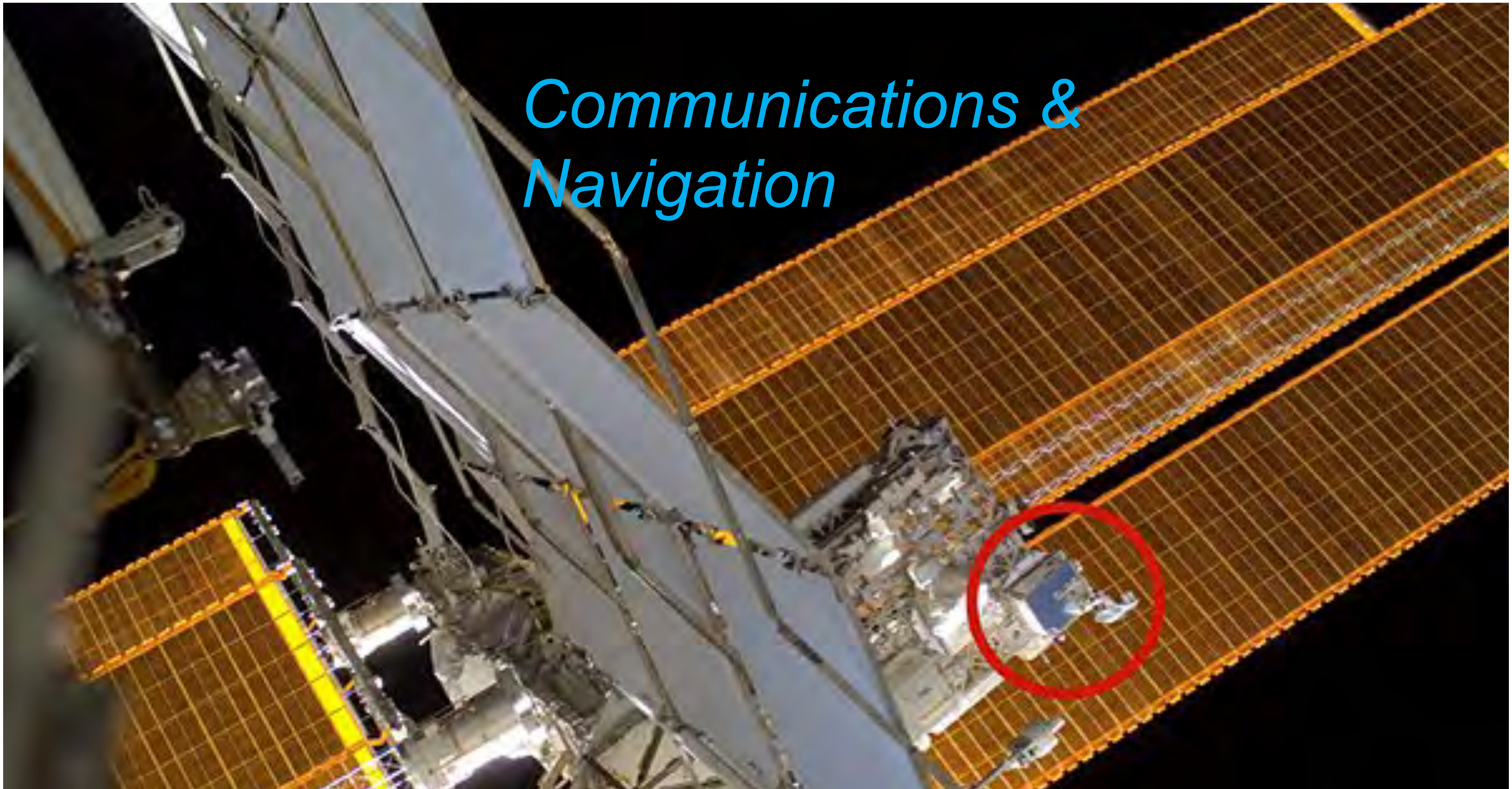
Robotics



Robotic Refueling Mission (RRM) is an external ***International Space Station*** experiment that paves the way for future robotic refueling missions. It demonstrates robotic refueling tasks and servicing technologies in a zero-g environment. It uses of the ISS Special Purpose Dexterous Manipulator (also known as "Dextre") to validate tasks, tools, and techniques needed to repair "legacy" satellites not designed to be refueled in orbit. Robotic refueling extends the lifetime of satellites, allowing owners and operators to gain additional years of use from assets already operating in space.

Source: ISS Program Scientist, NASA

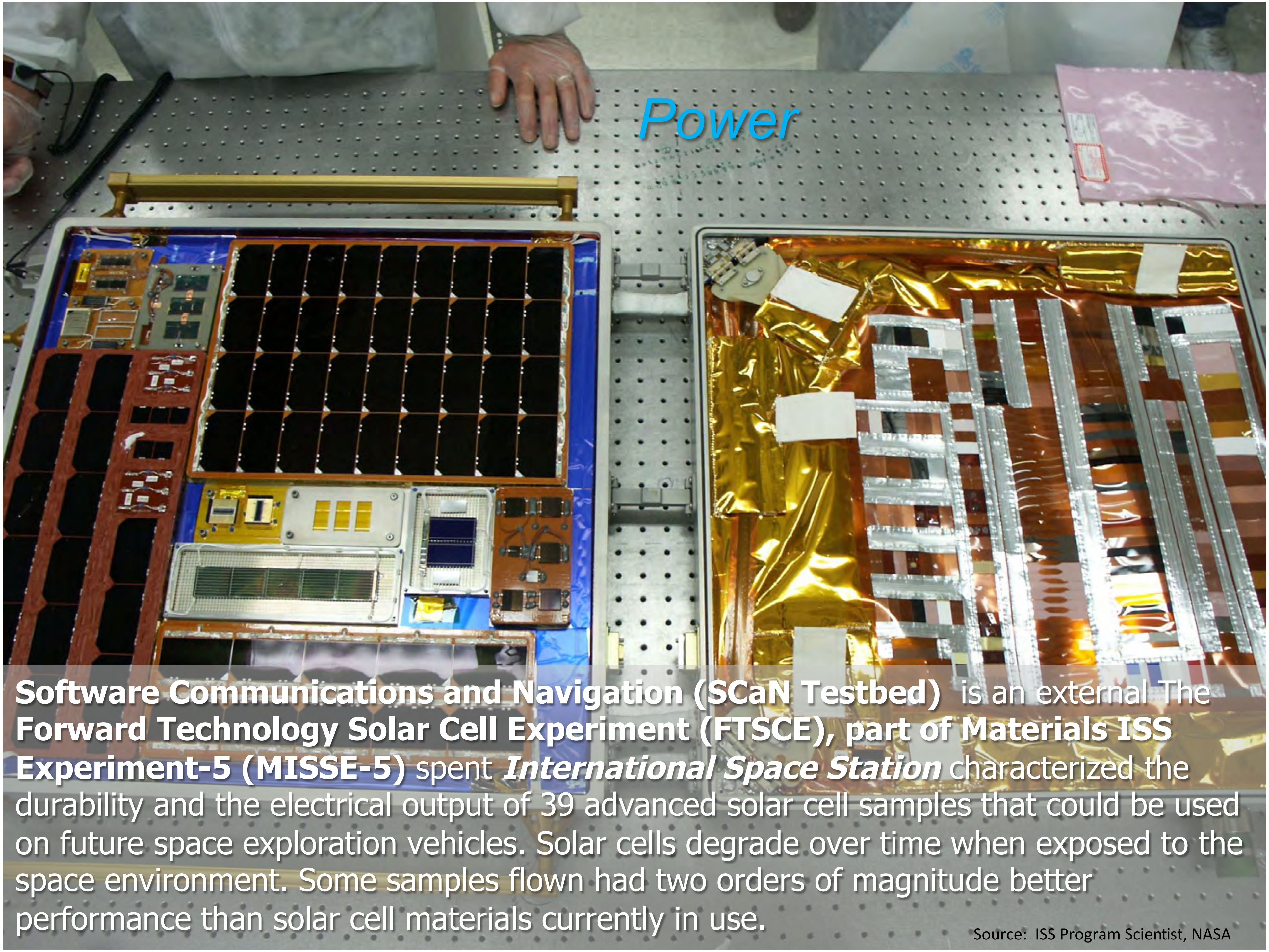
Communications & Navigation



Software Communications and Navigation (SCaN Testbed) is an external ***International Space Station*** that will provide an orbiting laboratory on space station for the development of Software Defined Radio (SDR) technology. It includes three SDR devices, each with different capabilities. These devices will be used by researchers to advance a new generation of space communications so that future NASA space missions will be able to return more scientific information and add new functions to accommodate changing mission needs.

Source: ISS Program Scientist, NASA

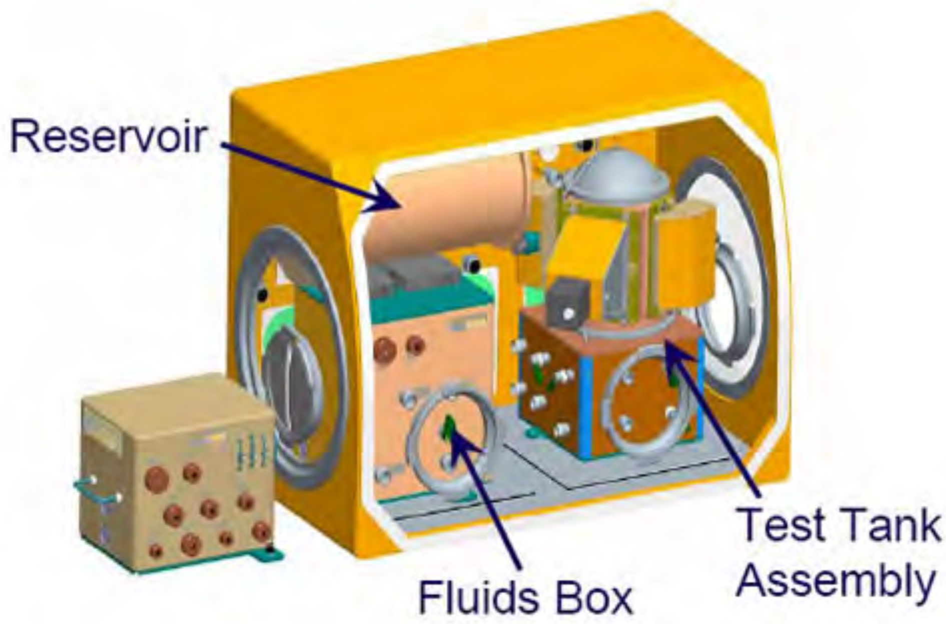
Power



Software Communications and Navigation (SCaN Testbed) is an external The **Forward Technology Solar Cell Experiment (FTSCE), part of Materials ISS Experiment-5 (MISSE-5)** spent ***International Space Station*** characterized the durability and the electrical output of 39 advanced solar cell samples that could be used on future space exploration vehicles. Solar cells degrade over time when exposed to the space environment. Some samples flown had two orders of magnitude better performance than solar cell materials currently in use.

Source: ISS Program Scientist, NASA

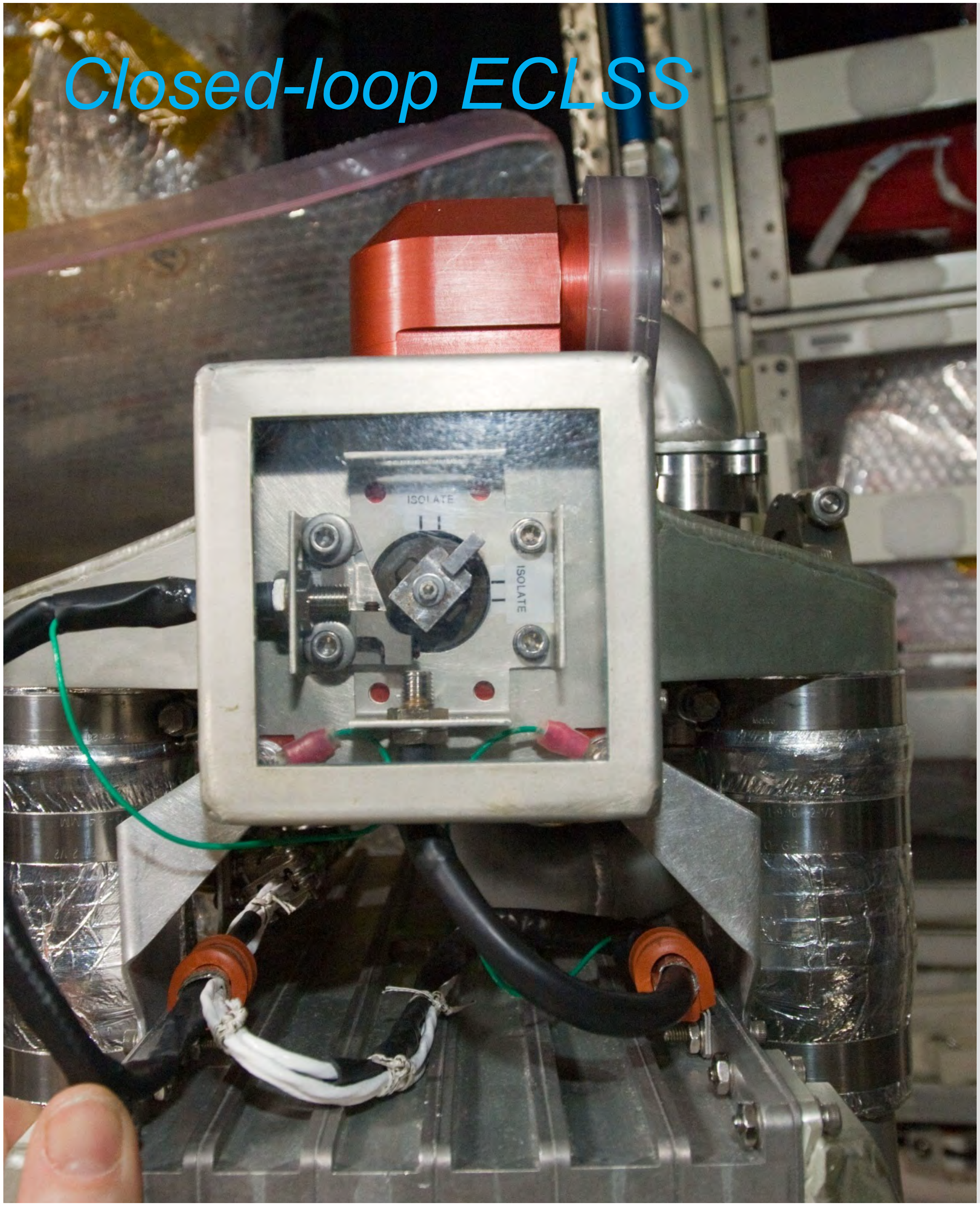
Thermal Control



Zero Boil-Off Tank Experiment (ZBOT) is an ***International Space Station*** demonstration to be conducted in the Microgravity Sciences Glovebox in late 2014. It will aid the design of long-term storage systems for cryogenic fluids. Simulated by Perfluoro-normal-Pentane (P-n-P), it will validate a Computational Fluid Dynamics (CFD) model for cryogenic storage in 1g and microgravity. This will support reductions in launch mass while insuring cost effective and reliable cryogenic storage for both life support and propulsion systems.

Source: ISS Program Scientist, NASA

Closed-loop ECLSS



Amine Swingbed is a prototype Carbon Dioxide removal system being testing on the ***International Space Station.*** Vacuum Regenerated Amine Systems have traditionally been applied to relatively short duration human space flight missions because water vapor is removed along with the CO2. Long duration missions need to recycle water. This system combines water recovery with the vacuum regeneration approach to measure its performance. This combined system uses less power and it is smaller in size than current technologies (note the small size compared to the fingers in the photo)..

Source: ISS Program Scientist, NASA

Fire Safety

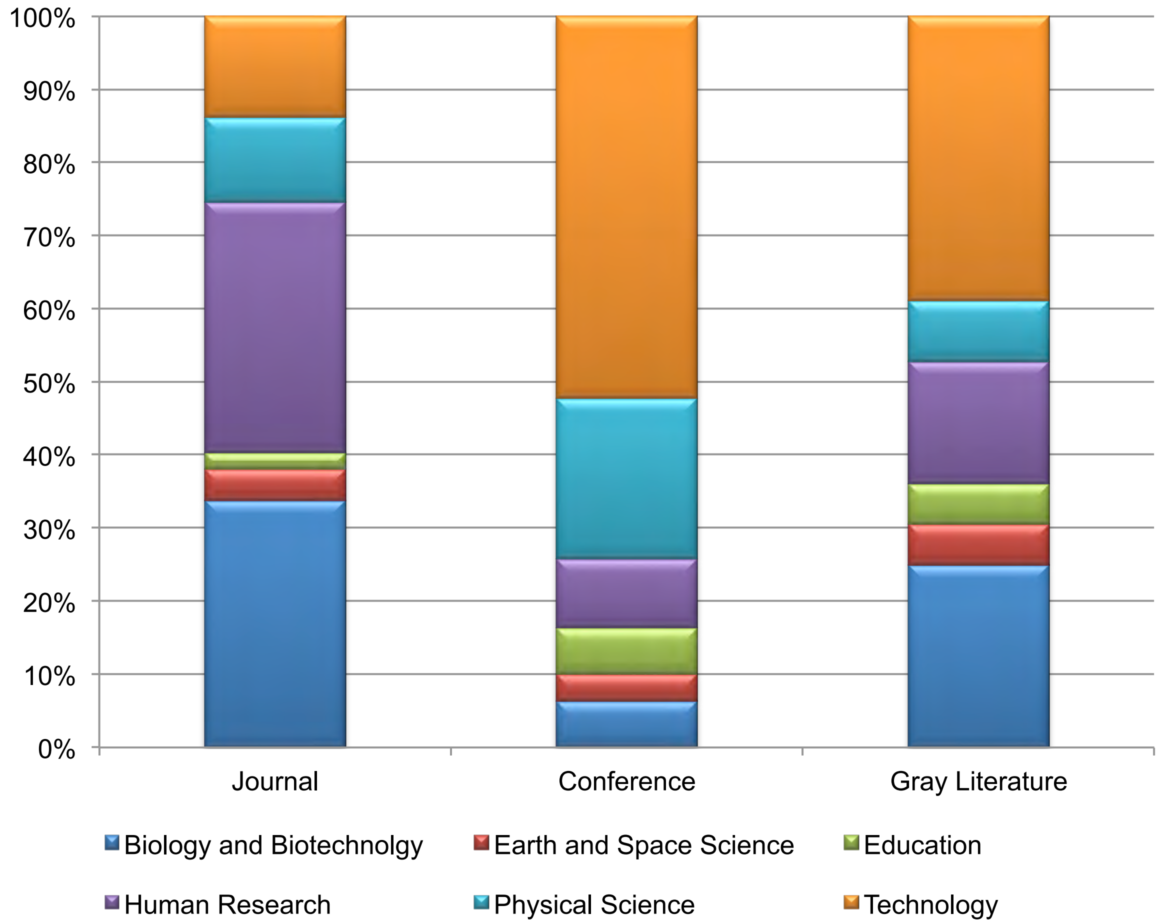
The Smoke Aerosol Measurement Experiment (SAME) on the ***International Space Station*** has revolutionized our understanding of the nature of smoke and soot in spacecraft fires, defining new requirements for future fire safety systems. Now ongoing on ISS, **Burning and Suppression of Solids in Space (BASS)** is looks at flames from a variety of burning materials with different shapes. Researchers use this investigation to assess the effectiveness of nitrogen in suppressing microgravity fires.

Current, Planned, or Proposed ISS Technology Demonstrations

Italic = NRC High Priority Technology that would benefit from ISS access
Underline = NRC High Priority Technology (focus for next 5 years)

- Robotics
  - *Next Gen Canadarm testing (CSA)*
  - *Robotic Assisted EVA's (Robonaut, NASA)*
  - METERON (ESA) and Surface Telerobotics
  - Delay Tolerant Network Robotic Systems
  - *Robotic Refueling Mission (CSA, NASA)*
  - <u>*Robotic assembly to optical tolerances (OPTIIX, NASA)*</u>
- Comm and Nav
  - OPALS – Optical Communication
  - X-Ray Navigation, (NICER/SEXTANT, NASA)
  - *Software Defined Radio (CoNNeCT/SCAN, NASA)*
  - Delay tolerant space networks
  - <u>*Autonomous Rendezvous & Docking advancements (ESA/JAXA)*</u>
  - <u>*Advanced optical metrology (sensing/mat'ls)*</u>
- Power
  - Regenerative fuel cells
  - <u>*Advanced solar array designs [FAST, IBIS, or other]*</u>
  - <u>*Advanced photovoltaic materials*</u>
  - *Battery and energy storage advancements [Li-Ion or other]*
- Thermal Control
  - High efficiency radiators
  - <u>*Cryogenic propellant storage & transfer*</u>
  - Advanced materials testing
- Closed Loop ECLSS
  - Atmospheric monitoring: ANITA2 (ESA), MIDASS (ESA), AQM (NASA)
  - <u>*Air Revitalization: Oxygen production, Next Gen OGA [Vapor Feed or other] (NASA)*</u>
  - <u>*Contaminated gas removal*</u>
  - <u>*Carbon Dioxide recovery: Amine swingbed and CDRA bed advancements*</u>
  - <u>*Advanced Closed-loop Life Support ACLS (ESA), MELiSSA (ESA),*</u>
  - <u>*Water/Waste: Electrochemical disinfection, Cascade Distillation System, Calcium Remediation, [Electrodialysis Metathesis or other]*</u>
- Other
  - *Spacecraft Fire Safety Demonstration*
  - <u>*Radiation protection/mitigation/monitoring*</u>
  - On-board parts repair and manufacturing
  - <u>*Inflatable Module (BEAM)*</u>

ISS Result Publications



- As of 10/5/12 a total of 783 results publications have been collected for ISS investigations for all of the partners.
- Of these:
  – 588 Journals
  – 159 Conferences
  – 36 Gray Literature (patent, book, magazine, technical paper, DVD)

Top Journals with ISS Results by Impact Factor/Eigenfactor

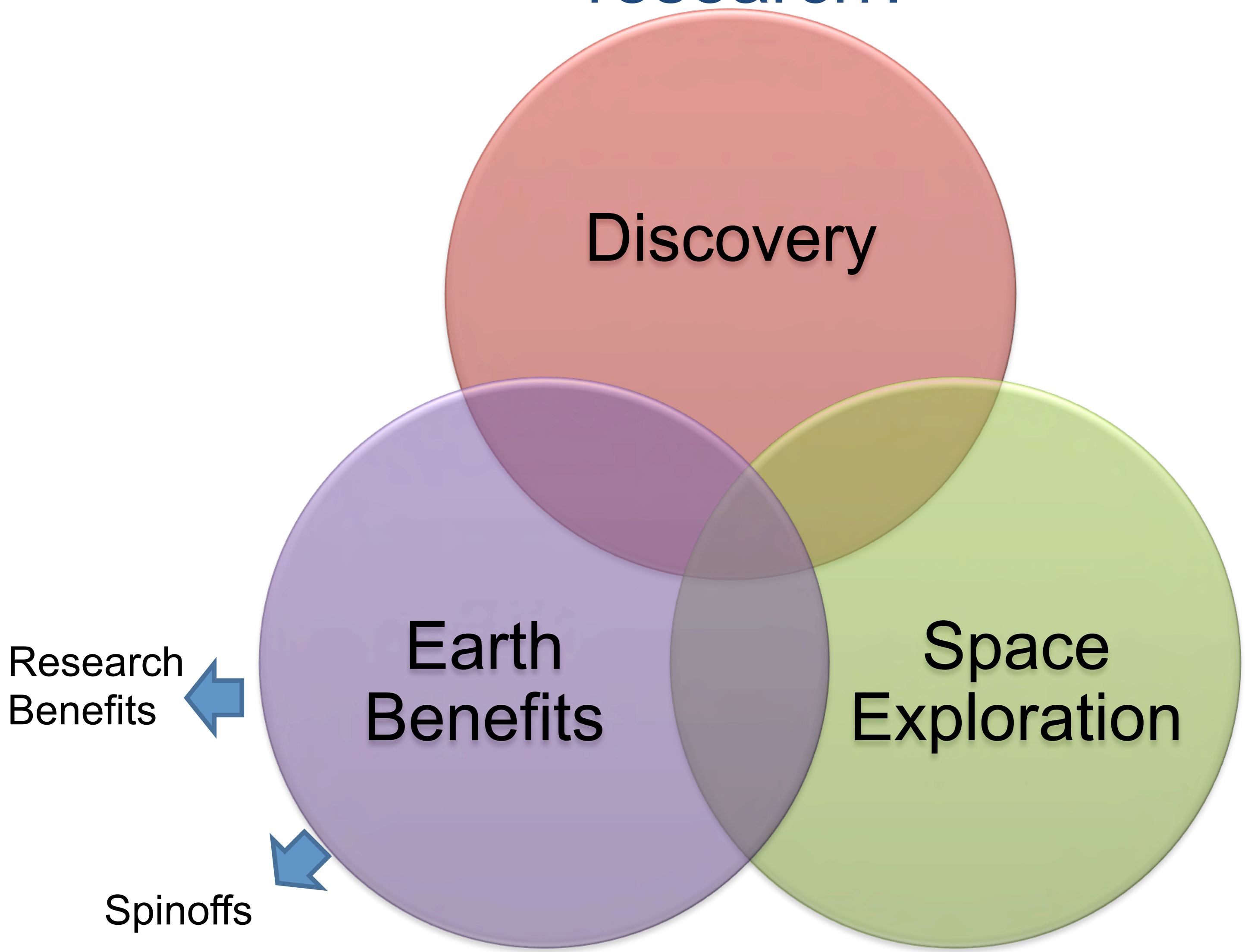
Journals	1Year Impact Factor	5 year Impact Factor	Eigenfactor
Nature	36.280	36.235	1.65524
Proceedings of the National Academy of Sciences of the United States of America	9.681	10.472	1.60168
Physical Review Letters	7.370	7.013	1.14457
Journal of Biological Chemistry	4.773	5.117	0.74213
PLoS ONE	4.092	4.537	0.50162
Journal of Neuroscience	7.115	7.915	0.44963
Journal of Geophysical Research	3.021	3.441	0.33245
Journal of Physical Chemistry B	3.696	4.061	0.24652
Geophysical Research Letters	3.792	3.759	0.23991
Langmuir	4.186	4.514	0.22322
NeuroImage	5.895	6.608	0.15356
Applied and Environmental Microbiology	3.829	4.453	0.12769
New Journal of Physics	4.177	3.773	0.11881
Brain Research	2.728	2.739	0.09356
FASEB Journal	5.712	6.340	0.08876
Journal of Urology	3.746	3.856	0.08303
Radiology	5.726	6.380	0.07346
American Journal of Physiology: Heart and Circulatory Physiology	3.708	3.878	0.06857
New Phytologist	6.645	6.693	0.06386
Opthalmology	5.454	5.567	0.05634
Acta Crystallographica Section D: Biological Crystallography	12.619	7.038	0.05384

ISS Patents from Research*

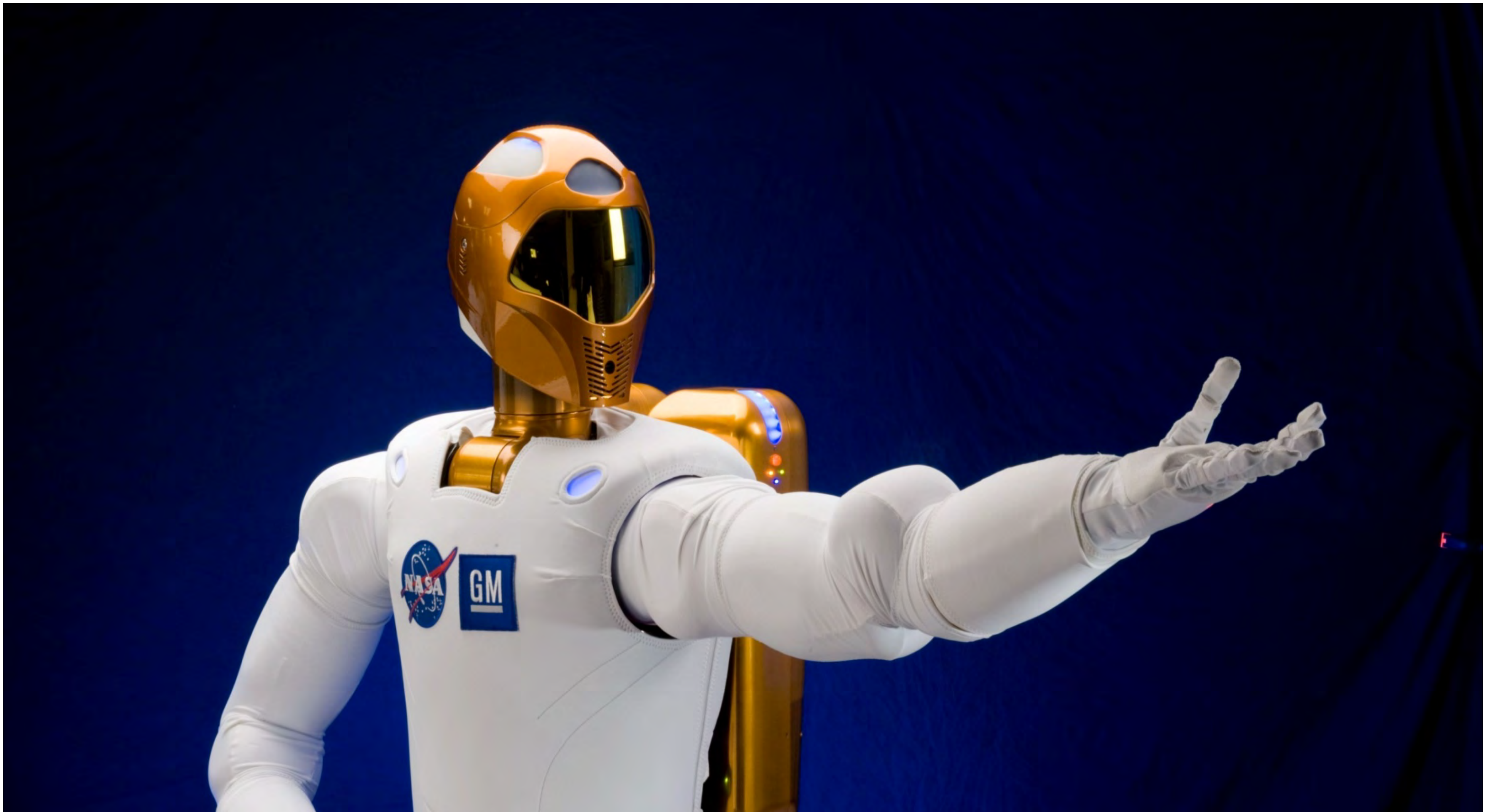
Discipline	Investigation	Patent
Facility	**CRIM-M**	Robyn Rouleau, Lawrence Delucas, Douglas Keith Hedden. Patent US6761861. High Density Protein Crystal Growth. Lawrence Delucas, Robyn Rouleau, Kenneth Banasiewicz. Patent US6623708. High Density Protein Crystal Growth.
Biology and Biotechnology	**MEPS**	Dennis R. Morrison. Patent 7295309. Microparticle analysis system and method.
Biology and Biotechnology	**NLP Vaccine**	Timothy G. Hammonds, Patricia L. Allen. Patent US20090258037. Vaccine Development Strategy using Microgravity Conditions.
Technology Development	**Amine Swingbed**	Walter C. Dean II. Patent 7637988. Swing Bed Canister with Heat Transfer Features.
Physical Science	**CFE**	Donald R. Pettit, Mark M. Wieslogel, Paul Concus, Robert Finn.Patent 8074827. Beverage cup for drinking use in spacecraft or weightless environments. Christopher M. Thomas, Yohghui Ma, Andrew North, Mark M. Weislogel. Patent 7913499. Microgravity condensing heat exchanger. Mark M. Wieslogel, Evan A. Thomas, John C. Graf . Patent 7905946. Systems and methods for separating a multiphase fluid.

* Does not include the patents from ISS systems development

What kind of benefits come from ISS research?



Julie A. Robinson, ISS Program Scientist



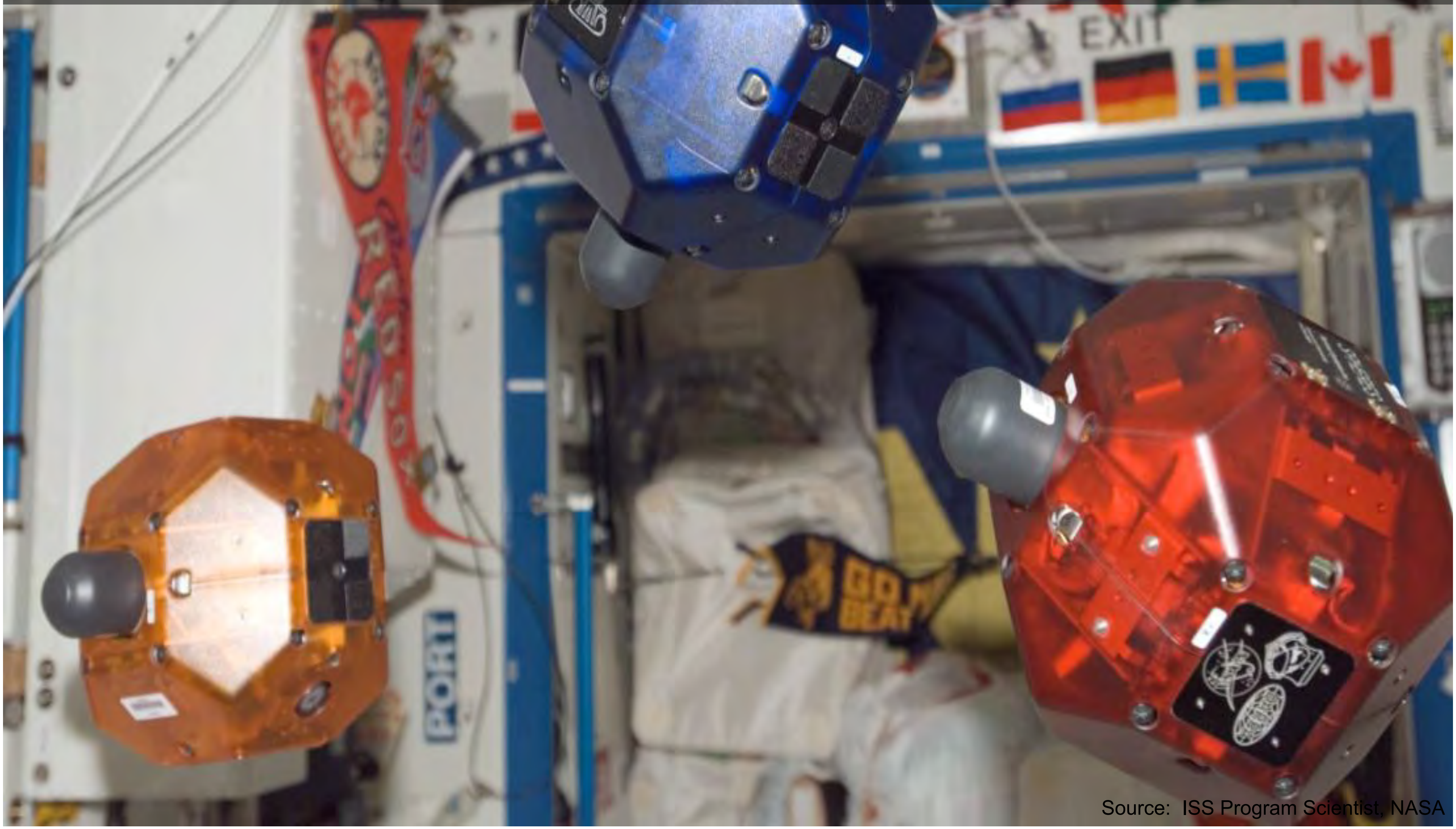
Human Helpers - Co-developed with General Motors (GM), Robonaut is the first humanoid robot in space, and its primary job for now is demonstrating how a dexterous robot can manipulate mechanisms in a microgravity environment, operate in the space environment for extended periods of time, assist with ***International Space Station*** tasks, and eventually interact with astronauts. GM plans to use the results in future advanced vehicle safety systems and manufacturing plant applications.

Source: ISS Program Scientist, NASA

Portable Test System - **Handheld devices enable crew on the ***International Space Station* to rapidly detect a variety of biological and chemical substances of concern to crew safety. This type of environmental testing technology has Earth-based, as well as future exploration missions and planetary protection applications.

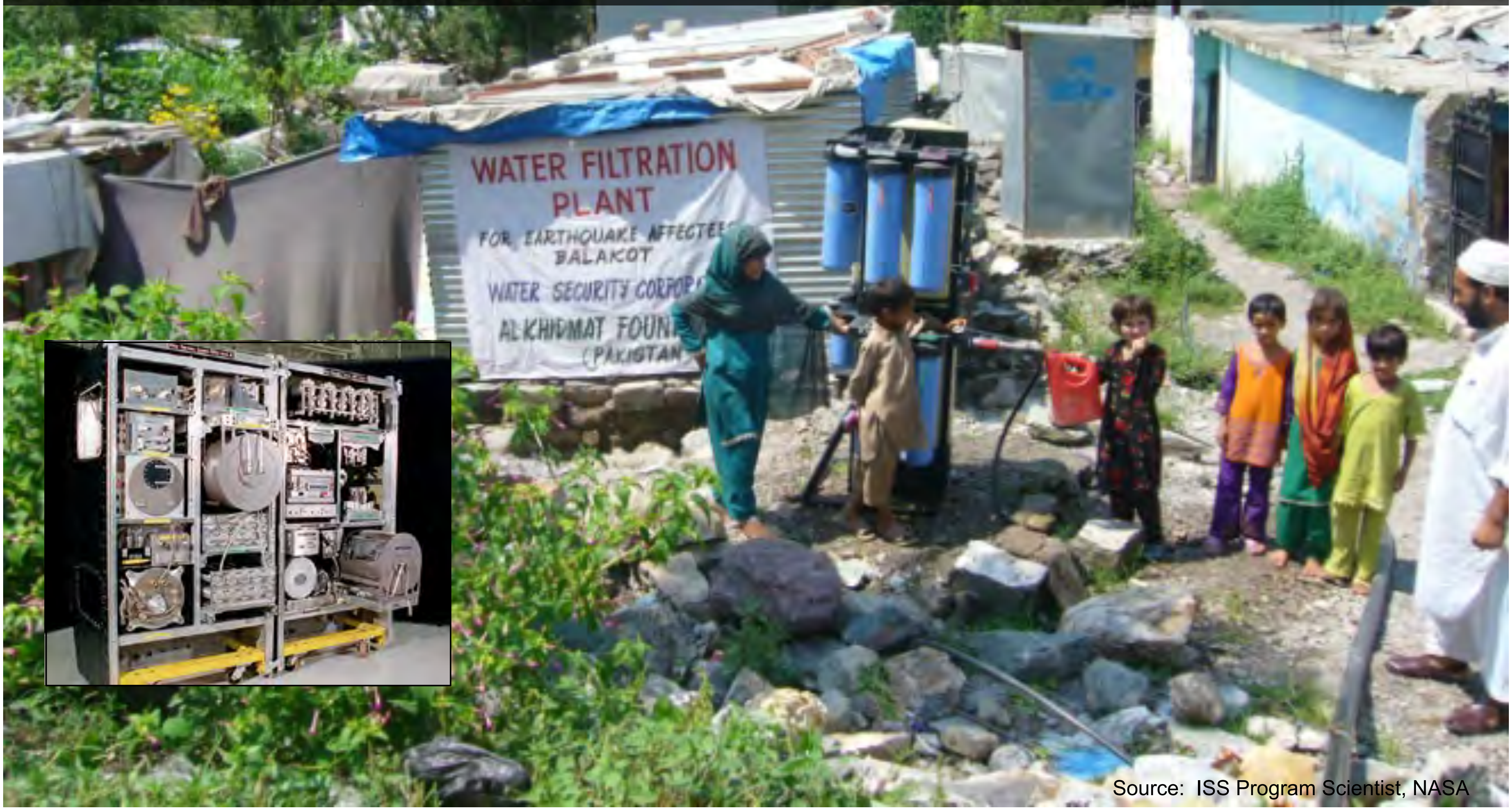
Source: ISS Program Scientist, NASA

Multi-body Maneuvering in Space – The Massachusetts Institute of Technology (MIT) is using color coded bowling-ball sized spherical satellites to demonstrate space-based autonomous rendezvous and docking on the ***International Space Station***. The results have applications for satellite servicing, space-based vehicle assembly and formation flying spacecraft configurations.

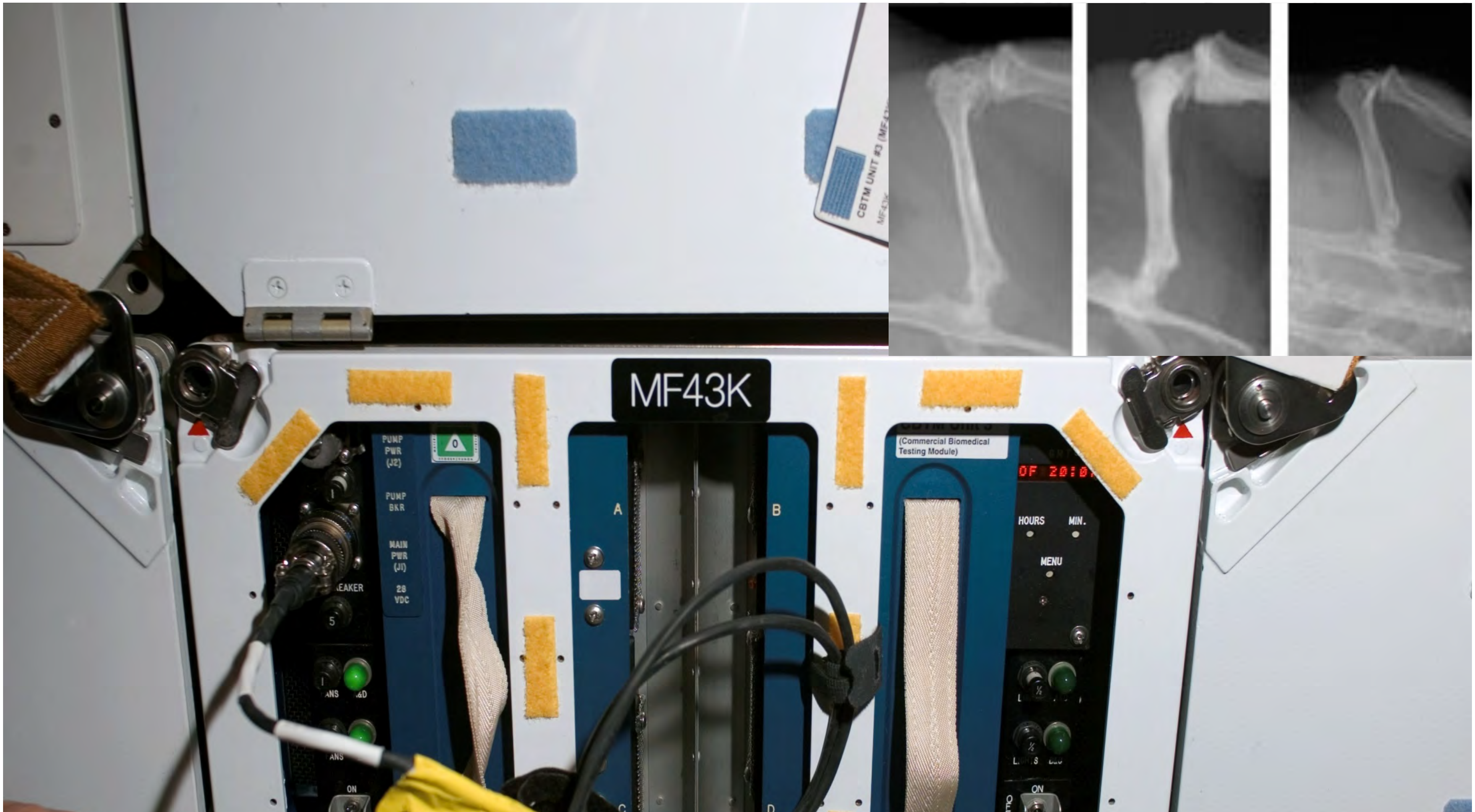


Source: ISS Program Scientist, NASA

Regen ECLSS – Water recycling, oxygen generation, and carbon dioxide removal are critical technologies for reducing the logistics re-supply requirements for human spaceflight. The ***International Space Station*** demonstration project is applying lessons learned form operational experiences to next generation technologies. The resin used in the ISS water processor assembly have been developed as a commercial water filtration solution for use in disaster and humanitarian relief zones.

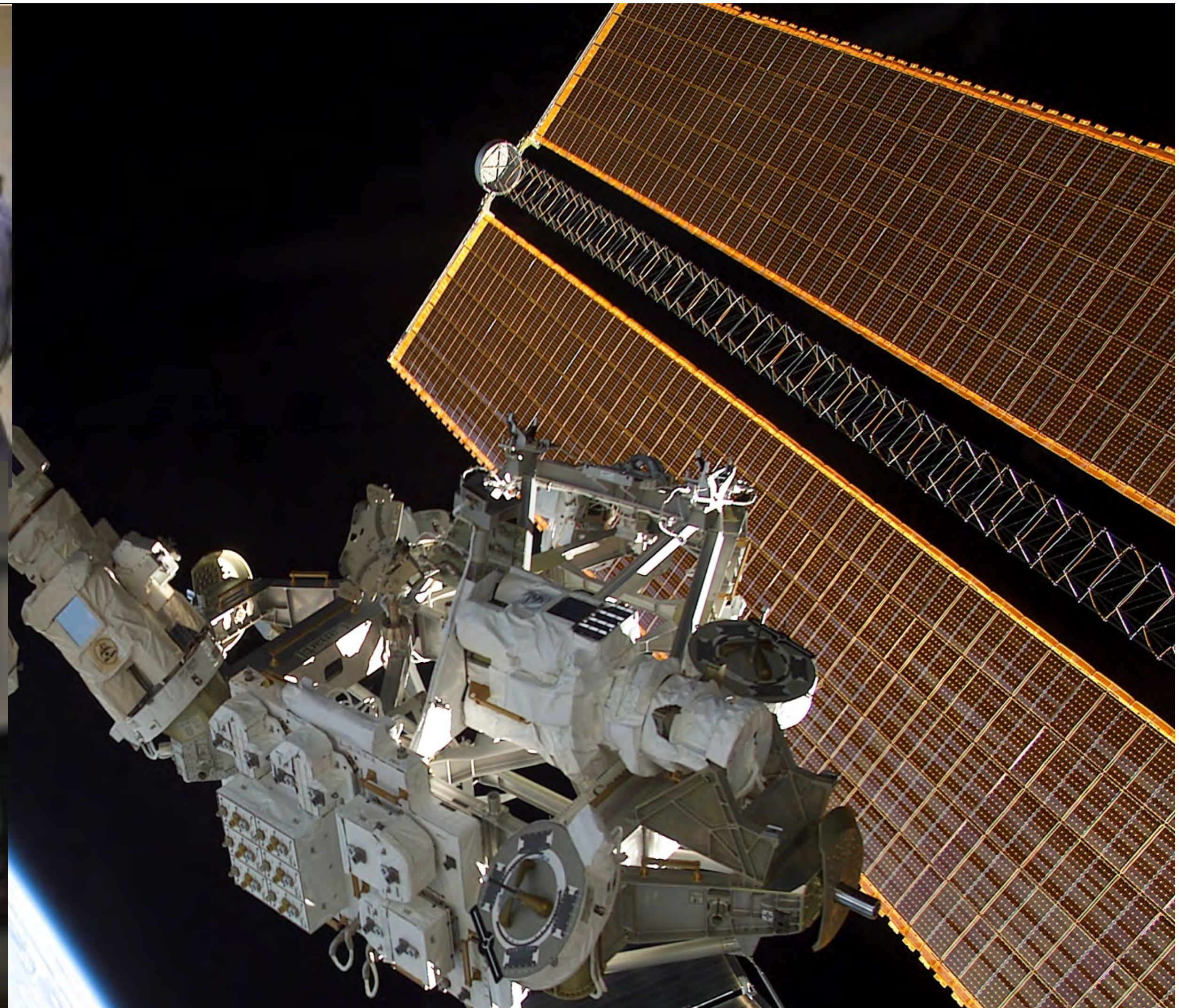


Source: ISS Program Scientist, NASA



Space Insights into Drug Function – In an investigation performed on a flight to the ***International Space Station*** by BioServe Space Technologies and Amgen Inc., found the use of the protein Osteoprotegerin (OPG) as a bone loss treatment nearly reversed bone resorption and declinations in bone strength in a rodent model. Results of this study also yielded fundamental insight into mechanisms of OPG function. An OPG pharmaceutical (Prolia™) was released in 2011 for use in severe bone loss in cancer patients.

Source: ISS Program Scientist, NASA



Medical Technology - The development and use of the robotic arm for space missions on the Space Shuttle and the ***International Space Station*** has led to the world's first MRI (Magnetic Resonance Imaging) compatible image-guided, computer-assisted device specifically designed for neurosurgery. The device now being used to augment surgeons' skills to perform neurosurgeries that are traditionally considered difficult or impossible, thus leading to better patient outcomes.

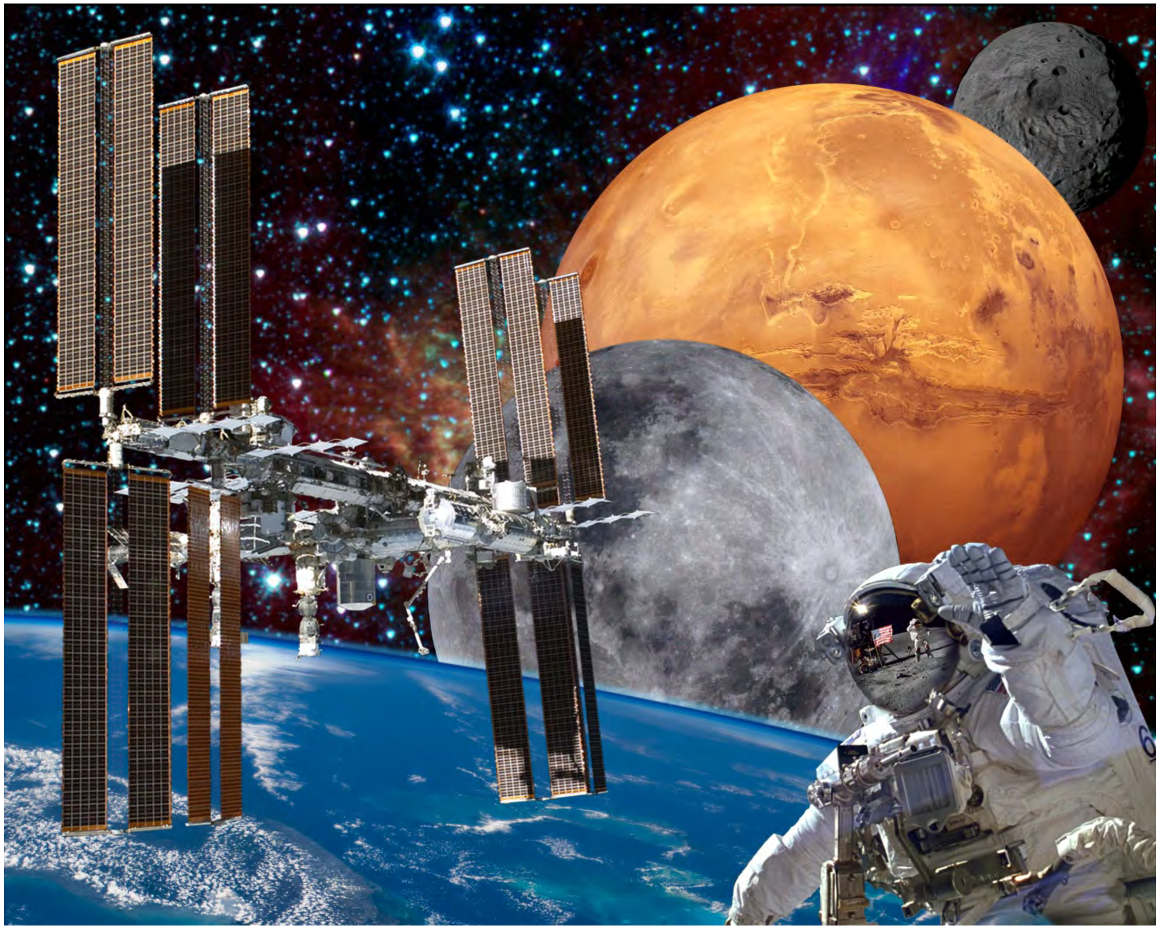
Source: ISS Program Sc

Examples of Major ISS Benefits from the Decade of Assembly

- Discoveries
  - MAXI black hole swallowing star (*Nature*)
  - Vision impacts and intracranial pressure (*Opthalmology*)
  - Microbial virulence (*Proc. Nat. Acad. Sci.)*
- Results with potential Earth benefit
  - Candidate vaccines for Salmonella and MRSA
  - Candidate treatment for prostate cancer
  - Candidate treatment for Duschenne's muscular dystrophy
- NASA Exploration Mission
  - Life support sustaining and reliability
  - Success in bone health maintenance resistive exercise (*J. Bone Mineral Res.*)
  - Models for Atomic Oxygen erosion in orbit
- Technology Spinoffs
  - Robotic assist for brain surgery
  - TiO2 for filtering bacteria from the air in daycares
  - Remotely-guided ultrasound for maternal care in remote areas

Our Future

- **ISS is a stepping stone to future human exploration**
  - Testing human endurance, equipment reliability, technologies, and life support systems essential for space exploration.
  - The global partnership, which constructed the space station, represents the foundation for the international technological collaboration needed to further humankind's reach into space.



Program Focus

Tactical

- Maintain/increase crewtime & resources for utilization
- Continue preparations for 1 year Increment
- FY13 budget posture
- Execute Space X2 Mission & complete Orbital 5K, 7K, and test flight
- ATV 4 launch
- HTV 4 launch
- Better utilize On-orbit stowage to improve crew time efficiency
- Commercial Crew Integration

Strategic

- Increase utilization of ISS as a National Lab
- Technology development and demonstration
- Increase utilization on ISS as a test bed for exploration
- Crew transportation plan
- Technical analysis & planning of ISS life extension
- Budget formulation to address challenges over the budget horizon.

ISS benefits for Humanity Document

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